PCT/IL 03/00062

מדינת ישראל
STATE OF ISRAEL

REC'D 26 AUG 2003
WIPO PCT

Ministry of Justice
Patent Office

משרד המשפטים
לשכת הפטנטים

This is to certify that annexed hereto is a true copy of the documents as originally deposited with the patent application of which particulars are specified on the first page of the annex.

זאת לתעודה כי רצופים בזה העתקים נכונים של המסמכים שהופקדו לכתחילה עם הבקשה לפטנט לפי הפרטים הרשומים בעמוד הראשון של הנספח.

PRIORITY DOCUMENT
SUBMITTED OR TRANSMITTED IN COMPLIANCE WITH RULE 17.1(a) OR (b)

This 29-07-2003 היום

מ. לסרי
ממונה על הבוחנים

רשם הפטנטים
Commissioner of Patents

BEST AVAILABLE COPY

נתאשר
Certified

לשימוש הלשכה
For Office Use

מספר: Number	150915
תאריך: Date	25-07-2002
הוקדם/נדחה: Ante/Post-dated	

חוק הפטנטים, תשכ"ז – 1967
PATENTS LAW, 5727-1967

בקשה לפטנט
Application For Patent

אני, (שם המבקש, מענו ולגבי גוף מאוגדת מקום התאגדותו)
I, (Name and address of applicant, and in case of body corporate-place of incorporation)

וט-טק בע"מ, חברה ישראלית מאיזור התעשיה , ת.ד. 12, קצרין 12900, ישראל
Vet-Tech Ltd., Israeli Company, of Industrial Area, P.O. Box 12 , Katserin 12900, ISRAEL

בעל אמצאה מכח הדין Right of Law ששמה הוא
Owner, by virtue of Right of Law of an invention the title of which is

(בעברית) (Hebrew)
מערכת הדמיה ושיטה להערכת מצב הגוף

(באנגלית) (English)
Imaging system and method for body condition evaluation

מבקש בזאת כי ינתן לי עליה פטנט
Hereby apply for a patent to be granted to me in respect thereof.

• בקשת חלוקה Application of Division	• בקשת פטנט מוסף Appl. for Patent of Addition	דרישת דין קדימה* Priority Claim		
מבקשת פטנט from application	• לבקשה/לפטנט to Patent/Appl.	מספר/סימן Number/Mark	תאריך Date	מדינת האיגוד Convention Country
No. ____ מס'	No. ____ מס'			
Dated מיום	Dated מיום			

P.o.A.: • יפוי כח:
עוד יוגש

המען למסירת מסמכים בישראל
Address for Service in Israel
C. 134077

REINHOLD COHN AND PARTNERS ריינהולד כהן ושותפיו
Patent Attorneys עורכי פטנטים
P.O.B. 4060, Tel-Aviv ת"ד 4060, תל-אביב

חתימת המבקש
Signature of Applicant
בשם המבקשים,
ריינהולד כהן ושותפיו
ע"י : -
S. Hirsch

היום 25 בחודש July שנת 2002
This 25 of July Year 2002

לשימוש הלשכה
For Office Use

טופס זה כשהוא מוטבע בחותם לשכת הפטנטים ומושלם במספר ובתאריך ההגשה, הנו אישור להגשת הבקשה שפרטיה רשומים לעיל.
This form, impressed with the Seal of the Patent Office and indicating the number and date of filing, certifies the filing of the application the particulars of which are set out above.

• מחק את המיותר
Delete whatever is inapplicable

מערכת הדמיה ושיטה להערכת מצב הגוף

Imaging system and method for body condition evaluation

Vet-Tech Ltd. **וט-טק בע"מ**

C. 134077

IMAGING SYSTEM AND METHOD FOR BODY CONDITION EVALUATION

FIELD OF THE INVENTION

The invention is generally in the field of monitoring techniques, and relates to a monitoring method and system for body condition evaluation, particularly useful for estimating the body condition score of dairy cows.

BACKGROUND OF THE INVENTION

Measuring a variety of attributes of animals, such as cows or beef cattle, is of high importance for farmers. Techniques aimed at determining animal traits, such as the identification of a specific animal, recognizing and determining the position of an animal or a specific part of it, or physical characteristics of an animal defining its economic value, have been developed, and are disclosed, for example, in the following patents.

US Patent No. 5,412,420 discloses a technique for measuring three-dimensional (3D) phenotypic characteristics of dairy cows. A 3D image is created by projecting several laser light beams and measuring their reflections with a single laser camera that scans a surface area of the animal and measures the distance at each point between the camera and the surface of the animal. By this, a total modeling of the animal's surface is provided. The camera generates a detailed map of the entire animal within the scanned space, assigning intensity and range values to each surface point that receives a laser signal. The obtained image is then analyzed by linear, angular or volumetric means. There are currently 15 conformation traits that are measured for Holstein Cows. After each trait is measured by the system, it is then converted to a scale of 1 to 50. Known as the rating of each trait, this conversion to a scale of 1 to 50 compares each cow measured to those represented within the biological extremes of the breed.

US Patent No. 6,234,109 discloses an apparatus and method for recognizing and determining the position of a specific part of an animal, e.g., the teat of a dairy cow, to guide an animal-related device towards the determined position of said part. The apparatus comprises a source of structured light for illuminating a surface region to enable identification of this specific part. The source of structured light is obtained by using a grid associated with a light-emitting element. The apparatus also comprises an image capture and processor means arranged to capture and process at least one image formed by said light, and control means to determine if the illuminated object includes said specific part by comparing the image of the illuminated object to reference criteria defining different objects, and if so, to establish the position thereof of the illuminated object.

US Patents Nos. 5,483,441 and 5,576,949 disclose a system for animal evaluation through image acquisition. According to this technique, an animal is evaluated to determine characteristics or traits thereof. The animal is evaluated as it moves through first and second scenes that correspond to different first and second fields of view along two essentially perpendicular lines of sight. Evaluation is carried out by comparing the so-obtained gray level to certain threshold values.

US Patent No. 5,398,290 discloses a system for measuring intramuscular fat in live cattle by an ultrasound device to produce ultrasound image of an interior muscle portion. The image contains speckles caused by the scattering of ultrasound waves by the intramuscular fat. Image data representative of the speckles are analyzed in a computer in terms of pixel gray areas to produce a measure of intramuscular fat.

The monitoring of body condition score (BCS) of dairy cows is a very important aid in defining their herd management. The BCS is known as a herd technique for determining the energy balance of dairy cows to define *inter alia* the amount of food needed for a particular group of dairy cows. According to this technique, an area on the cow's body in the vicinity of the tail head is inspected. This technique consists of the visual inspection of the vicinity of the tail head carried out by a skilled person, who determines the dairy cow's condition and assigns to the

specific cow a corresponding mark from several accepted marks. The results of such a manual inspection strongly depend on the experience of the specialist carrying out the inspection.

SUMMARY OF THE INVENTION

There is accordingly a need in the art to facilitate the automatic monitoring of the body condition score (BCS) of dairy cows, by providing a novel imaging method and system capable of determining the BCS of a specific dairy cow.

The main idea of the present invention consists of imaging a region of interest on the rear part of a dairy cow to obtain a three-dimensional representation of the region of interest and by that determine the BCS scale of the images cow. The region of interest includes the rear part of the cow in the vicinity of its tail head. This can be implemented by determining, from the 3D representation of the region of interest, a predetermined measurable parameter indicative of the curvature of the region of interest. Then, previously prepared reference data representative of the BCS scales and corresponding values of the predetermined measurable parameter can be used to analyze the determined value of this parameter for the specific imaged score and estimate the corresponding value of the BCS scale.

The term *"curvature"* signifies data indicative of a topographic map (surface relief) of the region of interest, and is actually representative of the surface defined by the volume of the region of interest. Preferably, the curvature is determined with respect to a predefined plane (reference plane) tangential to the region of interest, preferably, to the rear part of the cow at the point of both pins bones and tail.

There is thus provided according to one aspect of the present invention, a method for determining the body condition score (BCS) of a dairy cow, the method comprising:

(i) imaging a region of interest including the rear part of the cow in the vicinity of its tail head, and generating data indicative thereof;

(ii) processing the generated data and obtaining a three-dimensional representation of the region of interest;

(iii) processing said three-dimensional representation to determine the BCS of the dairy cow.

The imaging includes acquiring one or more image of the region of interest by illuminating the region of interest with structured light (i.e., a two-dimensional array of spatially separated light components) and collecting light scattered from the illuminated regions. The image is then processed to calculate the predetermined measurable parameter indicative of the curvature of the region of interest, and utilize the reference data to determine a value of BCS corresponding to the calculated value of the predetermined parameter. The image acquisition may be carried out by one or two pixel-array detectors. The reference data is previously prepared by applying measurements with both the conventional and inventive technique to dairy cows, and is representative of the body condition score scales (values) and corresponding values of the predetermined measurable parameter.

The measurable parameter indicative of the curvature of the region of interest may be at least one of the following: a distance (height) of the extreme point in the topographic map (determined as a distance between the reference plane and a point in the region of interest mostly distant from the reference plane); the area of a cross-section of the topographic map in a plane perpendicular to the reference plane (surface area defined by the illuminated surface regions in the plane perpendicular to the reference plane) and including the extreme point in the map; and at least a part of the volume defined by at least a predetermined region of the topographic map (illuminated surface regions) with respect to the reference plane.

According to another aspect of the present invention, there is provided a method for determining the body condition score (BCS) of a dairy cow, the method comprising:

- providing reference data representative of the BCS scales and corresponding values of a predetermined measurable parameter indicative of the curvature of a region of interest including the rear part of the cow in the vicinity of its tail head;

- imaging the region of interest by illuminating a two-dimensional array of spaced-apart illuminated regions within the region of interest, collecting light returned from the illuminated regions, and generating data indicative thereof;
- processing said generated data to obtain a three-dimensional representation of the region of interest and calculate a value of the predetermined measurable parameter from said three-dimensional representation; and
- utilizing said reference data to determine the BCS scale corresponding to the calculated value of said predetermined measurable parameter.

The processing of the data indicative of the acquired image includes determining a shift of the location of each of the illuminated regions on the surface of the cow's body caused by the curvature of the surface. If a single image is acquired, such a shift is a distance between the actual location of the illuminated region on the curved surface and corresponding location along the trajectory of the corresponding light component (i.e., a theoretical location of the corresponding region on the surface, if the surface were substantially flat). If two images are acquired with different angles of collection of light returned from the region of interest, the shift a distance between locations of the two illuminated regions of a matching pair of regions in the two images (Paralax). To this end, the processing preferably includes determining the central points of all the illuminated regions. The shift is indicative of the height of the respective point in the map (3D representation), and is determined utilizing data indicative of the detectors' location with respect to each other and relative to the region of interest, or the single detector's location relative to the region of interest and to the trajectories of the incident light components.

According to yet another aspect of the present invention, there is provided a system for determining the body condition score (BCS) of a dairy cow, the system comprising:

(a) an optical device including an illuminator operable to produce a two-dimensional array of spatially separated light components to thereby illuminate a two-dimensional array of regions within a region of interest on a body part of the dairy cow, and a light detection assembly operable for

acquiring at least one image of the illuminated body part by collecting light scattered therefrom and generating data indicative of the acquired image;

(b) a control unit connectable to the optical device, the control unit comprising a memory for storing reference data representative of the BCS scales and corresponding values of a predetermined measurable parameter that is indicative of the curvature of a region of interest including the rear part of a cow in the vicinity of its tail head; and a data processing and analyzing utility preprogrammed for processing the data indicative of the acquired image to calculate a value of the measurable parameter for the specific imaged cow, and analyze the calculated value with respect to the reference data to thereby determine the BCS scale of the specific dairy cow.

The illuminator may have one of the following configuration: it may be composed of a single light emitting element and a mask formed with a two-dimensional array of spaced-apart light transmitting regions spaced by light blocking regions; may be formed by a two-dimensional array of spaced-apart light emitting elements (lasers); may be a scanner, namely a light source (e.g. laser) that moves rapidly and scans the area; may be composed of one or more linear light sources or line scan; or may include a diffraction mask that creates a pattern.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to understand the invention and to see how it may be carried out in practice, preferred embodiments will now be described, by way of non-limiting example only, with reference to the accompanying drawings, in which:

Fig. 1 is a schematic illustration of the main components of the imaging system according to the present invention;

Figs. 2A and 2B illustrate two different examples, respectively, of an illuminator suitable to be used in the system of Fig. 1;

Fig. 3 illustrates the region of interest on the body part of the dairy cow illuminated by the illuminator of either one of Figs. 2A and 2B;

Fig. 4 is a flow diagram of the main operational steps in a method according to the invention;

Figs. 5A-5C exemplify the principles of calculation of a specific measurable parameter indicative of the curvature of the region of interest; and

Fig. 6 is a flow diagram of the image processing steps according to one embodiment of the invention utilizing acquisition of two images with different light collection angles.

DETAILED DESCRIPTION OF THE INVENTION

Referring to **Fig. 1**, the main components of an imaging system **100** according to the invention for determining the BCS of a dairy cow **DC**, are schematically illustrated. The cow may typically be provided with an identification tag (not shown) attached, for example, to its back leg. The imaging system **100** includes an optical device composed of an illuminator **104** and a detection assembly that includes a pixel-array detector (e.g., a camera) **106** and optionally an additional pixel-array detector **108** (shown in dashed lines). The illuminator **104** is constructed and operated to produce structured light in the form of a two-dimensional array of light beams, as will be described more specifically further below with reference to Figs. 2A and 2B. The cameras **106** and **108** are accommodated so as to acquire images of the same region of interest but with different angles of light collection, respectively. The output of the cameras is connectable to a control unit **110**, which is typically a computer device having a memory for storing *inter alia* predetermined reference data, a data processing and analyzing utility, as well as an input interface, display, etc.

Figs. 2A and 2B illustrate two possible implementations of the illuminator **104**. In the example of Fig. 2A, the illuminator **104** is composed of a matrix (two-dimensional array) of light-emitting elements, e.g. lasers, generally at **104A**, that are operable to produce a plurality of spatially separated light beams **112A** to thereby illuminate a matrix of spaced-apart regions (e.g., spots) within a region of interest. In the example of Fig. 2B, the illuminator **104** comprises a single light emitting element **104B** emitting a beam of light **113**, and a mask (grid) **116** in the form of a plurality

(two-dimensional array) of transmitting regions (e.g., holes) **118** spaced by non-transparent (blocking) regions. Hence, the mask (grid) **116** splits the emitted light beam **113** into a two-dimensional array of spatially separated light components **112B** to thereby produce a matrix of spaced-apart illuminated regions within the region of interest. Generally speaking, the light components produced either by the array of light-emitting elements **104A** or by the array of holes **118**, are arranged in a pre-defined pattern, e.g., a matrix shape, consisting of straight lines and rows.

The region of interest to be imaged for the purpose of the present invention includes the rear part of a dairy cow in the vicinity of the cow's tail head (**114** in Fig. 1). Hence, the illuminator **104** is oriented with respect to the cow's body part containing the region of interest so as to be placed behind and above the body part.

Fig. 3 shows the rear part of the cow (region of interest), with a matrix of illuminated regions (spots) **120** covering the entire imaged area. The main relevant parts for the scoring of the cow are the pins bone (Tuber ischii), the hooks bone (Tuber coaxe), the thurl and the sacral ligament.

The central area of the illuminated body part along the tail head is typically convex, while the regions at both sides of the tail head may be convex, flat, or concave. The degree of concavity of these regions is correlated with the body condition of a cow. According to the conventional technique, a skilled person (veterinary) inspects the rear part of the cow visually, and sometimes with manually appreciation, to estimate the degree of concavity and/or convexity of the relevant areas and determine the BCS of the cow, that defines the sub cutaneus amount of adiposic tissue which indicates the energy balance of the cow.

In order to enable automatic determination of the BCS of dairy cows, the present invention uses the imaging system of Fig. 1 (with one or two cameras) and a specific image processing technique. Initially, the required orientation between the system elements (the illuminator and one or two detectors) and the cow is provided. In general, images of the rear part of the cow are taken from up and behind the cow, at an elevation angle ranging between 45° and 90°. If the camera is mounted at an angle other than 45°, the image is first transformed to meet this requirement, for

uniformity purpose. This transformation may for example be a rotational transformation or a multiplication of rotational transformations that rotate the plane of image in the desired direction. For example, a suitable matrix (realizing the rotational transformation) multiplies the vector of points representing the spots of the image, to give the resulted vector, which represents the rotated plane, i.e., the rotated image.

As shown in **Fig. 4**, the main operational steps of the system are as follows. The optical device (illuminator **104** and detector) is operated to obtain data indicative of one or more images of the region of interest step A). This is implemented by illuminating the two-dimensional array of regions within the region of interest on the cow's body, collecting light returned (scattered) from the region of interest by one or two cameras, and generating output indicative of the so-acquired one or two images. This output data is received at the control unit **110** and processed by the data processing and analyzing utility (software) appropriately preprogrammed to obtain three-dimensional representation of the body surface within the region of interest (step B), and further process the 3D representation to determine the BCS of the imaged cow (step C). This is implemented by calculating a value of a predetermined measurable parameter indicative of the curvature of the region of interest and utilizing previously prepared (and stored in the memory of the control unit) reference data in the form of BCS scales and corresponding values of the predetermined measurable parameter to analyze the calculated value and determine the corresponding BCS scale.

Generally speaking, in order to calculate the measurable parameter indicative of the curvature of the region of interest, a shift of the location between the two images of each of the illuminated regions on the surface of the cow's body caused by the curvature of the surface is determined. If a single image is acquired, such a shift is a distance between the actual location of the illuminated region and a theoretical location of the corresponding region on the surface if being substantially flat, i.e., the corresponding location on the body surface along the trajectory of the corresponding light component). If two images are acquired, this shift is determined as a distance

between the two illuminated regions of a matching pair in the two images. The shift is indicative of the height of the respective point in the topography map (three-dimensional representation of the region of interest), which is determined by utilizing data indicative of the detectors location with respect to each other and relative to the region of interest, or the single detector location relative to the region of interest and to the illuminator trajectory.

The measurable parameter is indicative of the curvature of the region of interest, i.e., of a topographic map (surface relief) of the region of interest, and is actually representative of the volume of the region of interest. This curvature is determined with respect to a predefined reference plane **RP**, which in the present example is perpendicular to the line between the camera and the cow's rear part and is tangential to the region of interest, namely, to the rear part of the cow at the point of spin bone and tail head. Generally, the reference plane is selected as a plane in the vicinity of the tail head.

Figs. 5A-5C illustrate three examples of determination of the measurable parameter according to the present invention. Fig. 5A shows a 3D topography map **TP** reconstructed from the map(s) of points grabbed by one or two cameras from the region of interest (back of the cow). These points correspond to the scattering of the illuminated regions produced by the structured incident light. In the present example, a matrix of 120 laser sources is used as the illuminator. As shown in Fig. 5B, the measurable parameter may be a distance **h** (height) between the reference plane **RP** and the point $\mathbf{P_1}$ in the topography map mostly distant from the reference plane, or a cross-sectional area **CA** of a cross-sectioned segment **ES** of the map in a plane **P'** perpendicular to the reference plane and defined by a pair of most distant points $\mathbf{P_1}$ and $\mathbf{P_2}$ at opposite sides of the central plane of the image. Such a measurable parameter may be a volume **V** of at least a part of the topography map shown in Fig. 5A. The topography map is composed of a plurality of height levels defining contours of constant height levels (C_1-C_5) in the 2D representation of the 3D-topography map, shown in Fig. 5C. An arrow **B** represents the tail head, which is typically an axis of symmetry of the image of the structured light. Points **A** and **C** are

the end points in the 2D image along an envelope segment passing through the two points $\mathbf{P_1}$ and $\mathbf{P_2}$, which were defined above. Thus, there are several techniques for calculating the measurable parameter indicative of the curvature (the so-called Curvature Factor Measure or CFM). According to one technique, this parameter is the distance between the reference plane **RP** and the point on the line-segment **ES** maximally distant from the reference plane **RP**. According to another technique, this parameter is the cross-sectional area **CA** confined between the envelope segment **ES** and its projection on the reference plane **AC**. Preferably, the measurable parameter is the volume of at least a part of the topography map confined between the envelope segment, wherein the relevant part of the topography map is defined by a rectangle of a certain area (the entire structured light grid **LG** or a part of it) around the line segment **ES**, and the projection of this area onto the reference plane. This calculation practically comprises the integration of the height values of the illuminated regions (centers of these regions) over the image within the certain area, or, equivalently, summing the distances between the envelope segment and the reference plane over all the center points of the illuminated regions within the certain area. This can be written as:

$$CFM = \sum_{i,j}\left(P(i,j) - \mathrm{Re}\,f(i,j)\right) \times AreaUnit$$

wherein P(i, j) – Ref(i, j) is the height difference value between the envelope segment and the reference plane at point (i, j), and AreaUnit is the mean area around one illuminated region in the structured light matrix, or more precisely, the square of the mean distance between the centers of the neighboring illuminated regions in the structured light matrix. Hence, the CFM value may be given in volume units, e.g. cubic centimeters (cm^3).

The accuracy in calculating the centers of the illuminated regions is estimated to be about a tenth of a pixel. The accuracy in height is estimated to be about 1/2000 of the field-of-view of the camera, which for a measured volume of

600mm*600mm*600mm is about 0.5mm, less than the expected error due to the fur of a cow. The maximal expected depth of concavity is about 150mm. If the BCS value should be calculated with accuracy of 0.25, there are 16 different values between BCS 1 and 5. Thus, accuracy in height of 150mm/16 or 9.375mm is sufficient for the purposes of the present invention. The estimated accuracy is 5 times better. The system today deals with the following 13 BCS scale values: 1.00, 1.50, 2.00, 2.25, 2.50, 2.75, 3.00, 3.25, 3.50, 3.75, 4.00, 4.50, and 5.00. With the accuracy of 1 decimal score (0.1), 50 BCS scales can be achieved (1.00, 1.10, 1.20,.....4.80, 4.90, 5.00).

The rear part of a cow may comprise deep valleys (for thin cows of low BCS) or shallow valleys, or may have no valleys at all (for normal cows with moderate BCS). Accordingly, the CFM can be positive, zero or negative. The inventors have found that for cows with BCS of about 3.50, the value of CFM is about zero. Thus, for cows of the BCS below 3.50 the value of CFM is negative, while cows of BCS above 3.50 have a positive value of CFM.

Using reference data in the form of a large set of scans of cows of known BCS values enables to calculate the CFM values resulting from the image processing for each scan and match it with the given BCS value. Hence, a correlation between CFM and BCS values can be determined. This correlation is not necessarily a linear transformation and might not even be represented by any mathematical formula at all, but is simply experimentally matched. In such a case, the match is represented in a table correlating between pairs of points, where the first point is a CFM value, and the other point is a BCS value.

Reference is now made to **Fig. 6** exemplifying a flow diagram of the operational stages of the image processing considering the image acquisition with two cameras (**106** and **108** in Fig. 1). In this case, the data to be processed is indicative of two images of the cow's rear part concurrently acquired by two cameras with two different angles of light collection, as is illustrated in Fig. 1.

Initially, a calibration stage is carried out, in order to compensate for internal variables of the cameras and for external variables of the cameras (step I). Such

internal variables include magnification, calibration and Distortion, while external variables of the cameras are for example the relative angles of the cameras in space (step I).

Processing of data received from the two cameras includes finding the matching pairs of illuminated regions, i.e., two images of the same illuminated region. Since such an illuminated region is practically not a point-like region, but a spot, elongated regions, lines, etc., the processing starts with finding the center of each of the illuminated regions in each of the two images. For light spots, the center is simply the geometrical center of each spot. The finding of the center can be done by any known suitable method, for example by detecting extreme locations of the illuminated region along two mutually perpendicular axes and calculating the center of the so-formed geometrical structure. For lines, the central point is defined as the point of maximal light intensity along the illuminated line (step II).

Then, matching pairs between the central points of the illuminated regions in the two images are determined, i.e., location of each illuminated region in the first image is matched with the corresponding location in the second image (step III). In general, imaging of a flat surface, e.g. a flat wall, using a matrix of illuminated spots would result in an image composed of a matrix of spots with the same pattern as that of the matrix of incident light components, e.g., a two-dimensional linear array. When illuminating the rear part of a cow, which is a curved surface, the locations of some of the spots are shifted from those in the flat-surface image, due to the surface curvature. Moreover, some of these spots, e.g. at places of extreme curvature, where one spot may coincide with another spot, may not appear in the image at all. Hence, there can be unmatched spots in the two images, but it should be understood that the matched spot in one image is always associated with a single spot in the other image.

Data representative of the so-obtained two-dimensional coordinates of the pairs of matched illuminated regions (central points thereof) and data representative of the three-dimensional (3D) location of the two cameras are then analyzed to thereby enable calculation of the 3D locations of the respective illuminated regions on the illuminated surface area of the cow (step IV). This can be done by the

triangulation method. The principles of this technique are know *per se*, and therefore need not be described in detail, except to note the following. The triangulation technique is based on measuring a shift (called parallax) of an imaged object in two images. More specifically, when the object is imaged by two cameras distanced from each other (or by one camera taking two different shots at two places far apart), the relative place of the object is shifted between the two images, i.e. the object's image changes its location relative to the background. Measuring this shift allows for determining the distance of the object from the background or from the cameras, or finds its location in space. By this, the 3D locations of all the illuminated regions within the region of interest are calculated, assuming that the peripheral illuminated regions may serve as the background for the calculation in the first approximation. If the peripheral illuminated regions are not shifted due to the surface curvature, or if such a shift is negligible, the use of a single camera is sufficient to calculate the deviation of each of the interior illuminated regions from its assumed position in the absence of the surface curvature. This shift, together with the relative locations of the camera and the light source from the region of interest, enable to calculate the "height" of each illuminated region with respect to an imaging plane.

Thereafter, a two-dimensional (2D) representation of the 3D cow's rear part is obtained in the following manner. First, the reference plane **RP** is selected. Then, the points calculated in the previous stage are drawn on the selected reference plane. In order to do so, their coordinates may need to be transformed according to the coordinate system of the chosen plane. The first two coordinates of each point (X_i, Y_i) represent its place within the reference plane **RP**, while the third coordinate (Z_i) denotes the height of the point above/beneath the reference plane **RP**. In a further stage, the so-obtained data indicative of the points' heights is used to calculate the CFM indicative of the cow's body condition score, as described above (step V). The 3D virtual surface is thus the basic for the CFM measurements. The BCS is then obtained from the CFM value together with the reference data, as described above (step VI).

It should be understood, although not specifically shown, that in the case of a single image, the image processing is generally similar to the above-described example of two cameras, and differs therefrom in the following two modifications. (a) Finding of matching pairs of points (centers of the illuminated spots) is eliminated since there is a single image only; and (b) Calculation of the 3D location of a given illuminated region on the cow's body part is carried out by taking into account the location of the light source and the direction of the light beam from the light source to the relevant light spot along the trajectory of the beam. These modifications actually affect the determination of the shift to calculate the 3D location of each illuminated region, i.e. to reconstruct the topographic map. As indicated above, the shift between the actual location of the illuminated region and a theoretical location of the corresponding region on the surface if being substantially flat is determined in order to calculate the CFM.

Those skilled in the art will readily appreciate that various modifications and changes can be applied to the embodiments of the invention as hereinbefore exemplified without departing from its scope defined in and by the appended claims.

CLAIMS:

1. A method for determining the body condition score (BCS) of a dairy cow, the method comprising:

(i) imaging a region of interest including the rear part of the cow in the vicinity of its tail head, and generating data indicative thereof;

(ii) processing the generated data and obtaining a three-dimensional representation of the region of interest;

(iii) processing said three-dimensional representation to determine the BCS of the dairy cow.

2. The method according to Claim 1, wherein the determination of the BSC comprises determining from said three-dimensional representation a predetermined measurable parameter indicative of the curvature of the region of interest.

3. The method according to Claim 2, wherein said processing of the three-dimensional representation utilizes reference data representative of the BCS scales and corresponding values of said predetermined measurable parameter indicative of the curvature of the region of interest.

4. The method according to Claim 2 or 3, wherein said predetermined measurable parameter indicative of the curvature of the region of interest is representative of a volume of the region of interest.

5. The method according to any one of Claims 2 to 4, wherein said specific measurable parameter is indicative of the curvature of the surface of the region of interest with respect to a predefined reference plane.

6. The method according to Claim 5, wherein said reference plane is tangential to the rear part of the cow at the point of pin bone and tail.

7. The method according to Claim 5, wherein said specific measurable parameter is representative of at least one of the following: a distance between the reference plane and a point in the region of interest mostly distant from said reference plane; a surface area defined by illuminated surface regions in a plane perpendicular

to said reference plane and including the mostly distant point; and at least a part of a volume defined by the illuminated surface regions and said reference plane.

8. The method according to any one pf preceding Claims, wherein said imaging comprises illumination of a two-dimensional array of regions within the region of interest and collection of light scattered from the illuminated regions.

9. The method according to Claim 8, wherein said imaging comprises directing a two-dimensional array of spatially separated light components towards the region of interest.

10. The method according to Claim 9, wherein said two-dimensional array of incident light components is produced by passing a light beam generated by a light emitting element through a mask accommodated in the path of the emitted light beam, thereby splitting the emitted light beam into the two-dimensional array of the spatially separated light components.

11. The method according to Claim 9, wherein said two-dimensional array of incident light components is produced by light generated by a two-dimensional array of light emitting elements, respectively.

12. The method according to any one of preceding Claims, wherein the processing of said generated data comprises determining a shift of a location of each of the illuminated regions within the array of the illuminated regions caused by the curvature of the illuminated surface, said shift being indicative of said curvature.

13. The method according to Claims 4 and 12, wherein said shift is representative of a distance between the respective illuminated region and said reference plane.

14. The method according to Claims 12 or 13, wherein said imaging of the region of interest comprises acquiring a single image of the region of interest, said shift being a distance between the location of the illuminated region on the curved surface of the body part and a corresponding location along the trajectory of the corresponding light component.

15. The method according to Claim 12 or 13, wherein said imaging of the region of interest comprises acquiring two images of the region of interest with

different angles of collection of light returned from the region of interest, said shift being a distance between locations of the two illuminated regions of a matching pair of regions in the two images.

16. The method according to any one of Claims 12 to 15, wherein the processing of said generated data comprises determination of central points of all the illuminated regions.

17. A method for determining the body condition score (BCS) of a dairy cow, the method comprising:

- providing reference data representative of the BCS scales and corresponding values of a predetermined measurable parameter indicative of the curvature of a region of interest including the rear part of the cow in the vicinity of its tail head;
- imaging the region of interest by illuminating a two-dimensional array of spaced-apart illuminated regions within the region of interest, collecting light returned from the illuminated regions, and generating data indicative thereof;
- processing said generated data to obtain a three-dimensional representation of the region of interest and calculate a value of the predetermined measurable parameter from said three-dimensional representation; and
- utilizing said reference data to determine the BCS scale corresponding to the calculated value of said predetermined measurable parameter.

18. A system for determining the body condition score (BCS) of a dairy cow, the system comprising:

(a) an optical device including an illuminator operable to produce a two-dimensional array of spatially separated light components to thereby illuminate a two-dimensional array of regions within a region of interest on a body part of the dairy cow, and a light detection assembly operable for acquiring at least one image of the illuminated body part by collecting light scattered therefrom and generating data indicative of the acquired image;

(b) a control unit connectable to the optical device, the control unit comprising a memory for storing reference data representative of the BCS scales and

corresponding values of a predetermined measurable parameter that is indicative of the curvature of a region of interest including the rear part of a cow in the vicinity of its tail head; and a data processing and analyzing utility preprogrammed for processing the data indicative of the acquired image to calculate a value of the measurable parameter for the specific imaged cow, and analyze the calculated value with respect to the reference data to thereby determine the BCS scale of the specific dairy cow.

19. The system according to Claim 18, wherein the illuminator comprises a light emitting element operable to emit a light beam, and a mask accommodated in the path of the emitted light beam to split it into the two-dimensional array of spatially separated light components.

20. The system according to Claim 18, wherein said illuminator comprises a two-dimensional array of light emitting elements operable to emit the two dimensional array of light beams, respectively.

21. The system according to any one of Claims 18 to 20, wherein the detection assembly comprises a single pixel-array detector.

22. The system according to any one of Claims 18 to 20, wherein the detection assembly comprises two pixel-array detectors.

23. The system according to Claim 22, wherein said two pixel-array detectors are oriented with respect to the region of interest so as to acquire two images with different collection angles, respectively.

24. The system according to any one of Claims 18 to 23, wherein said data processing and analyzing utility is operable to determine a shift of a location of each of the illuminated regions within the array of the illuminated regions caused by the curvature of the illuminated surface, said shift being indicative of said curvature

25. The system according to Claims 21 and 24, wherein said shift is a distance between the location of the illuminated region on the curved surface of the body part and a corresponding location along the trajectory of the corresponding light component.

26. The system according to Claims 23 and 24, wherein said shift is a distance between locations of the two illuminated regions of a matching pair of regions in the two images.

27. The system according to any one of Claims 24 to 26, wherein the processing and analyzing utility is operable to determine central points of all the illuminated regions.

28. The system according to any one of Claims 18 to 27, wherein said predetermined measurable parameter indicative of the curvature of the region of interest is representative of a volume of the region of interest.

29. The system according to any one of Claims 18 to 28, wherein said predetermined measurable parameter is indicative of the curvature of the surface of the region of interest with respect to a predefined reference plane.

30. The system according to Claim 29, wherein said reference plane is tangential to the rear part of the cow at the point of spin bone and tail.

31. The system according to Claim 28 or 29, wherein said predetermined measurable parameter is representative of at least one of the following: a distance between said reference plane and a point on the region of interest mostly distant from said reference plane; a surface area defined by the illuminated surface regions in a plane perpendicular to said reference plane and including the mostly distant point; and at least a part of a volume defined by the illuminated surface regions and said reference plane.

32. The system according to Claims 24 and 29, wherein said shift is representative of a distance between the respective illuminated region and said reference plane.

For the Applicants,
REINHOLD COHN AND PARTNERS
By: S. Hirsch

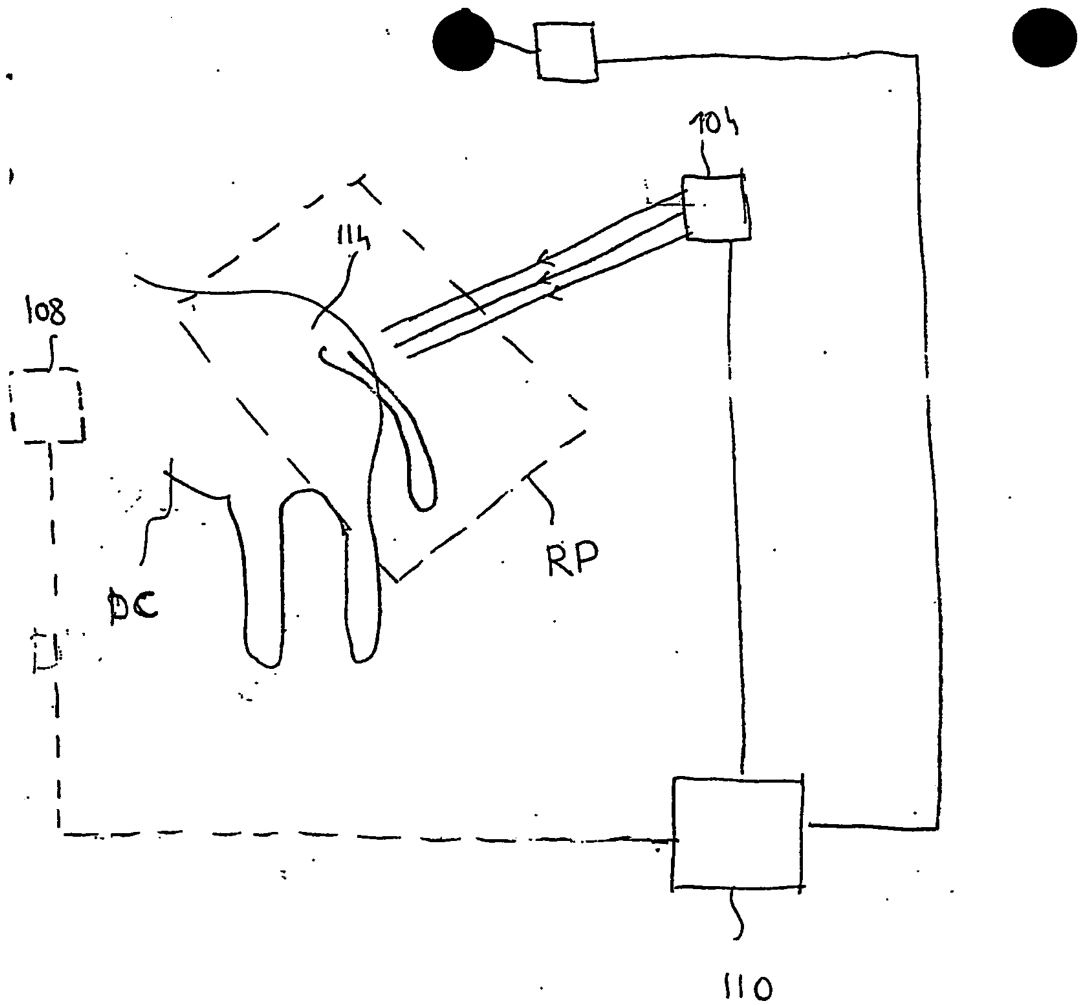


Fig. 1

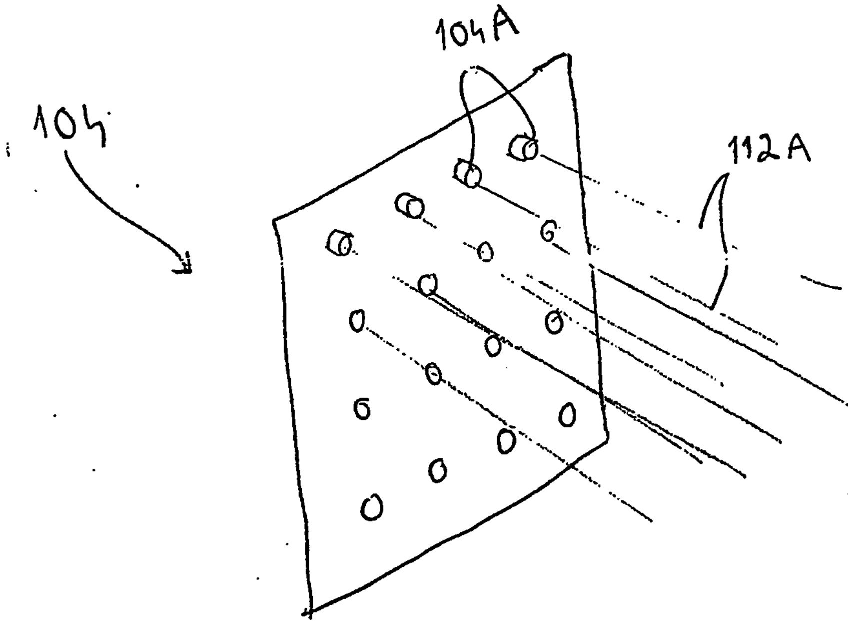


Fig. 2A

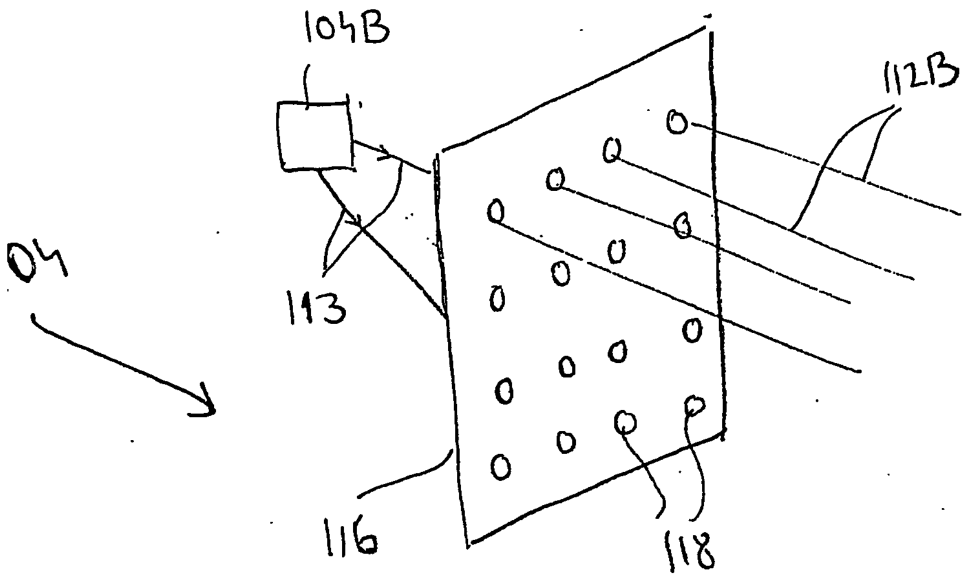


Fig. 2B

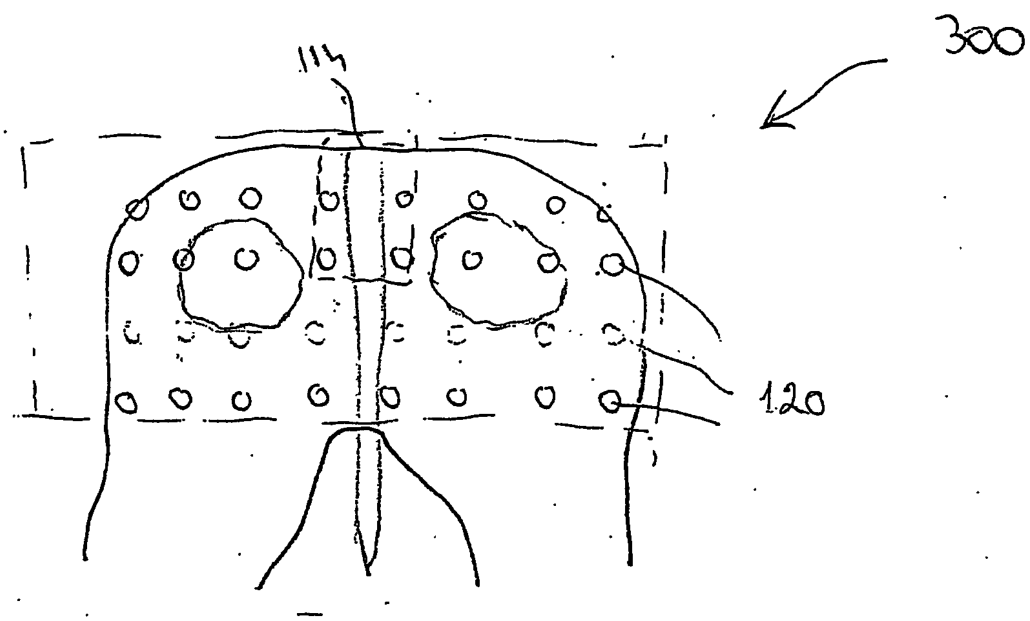


Fig. 3.

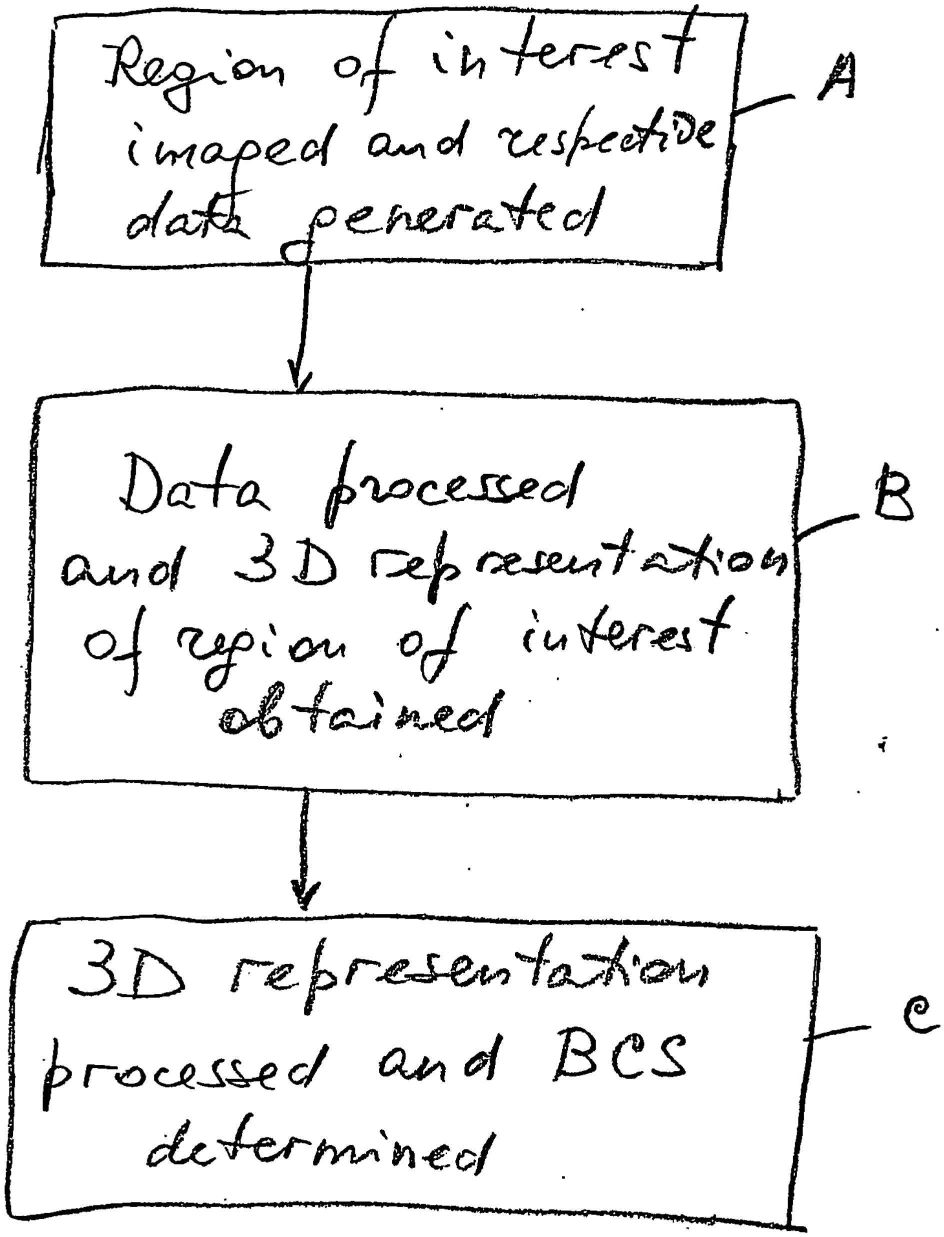

Region of interest imaged and respective data generated
A
Data processed and 3D representation of region of interest obtained
B
3D representation processed and BCS determined
C

Fig. 4

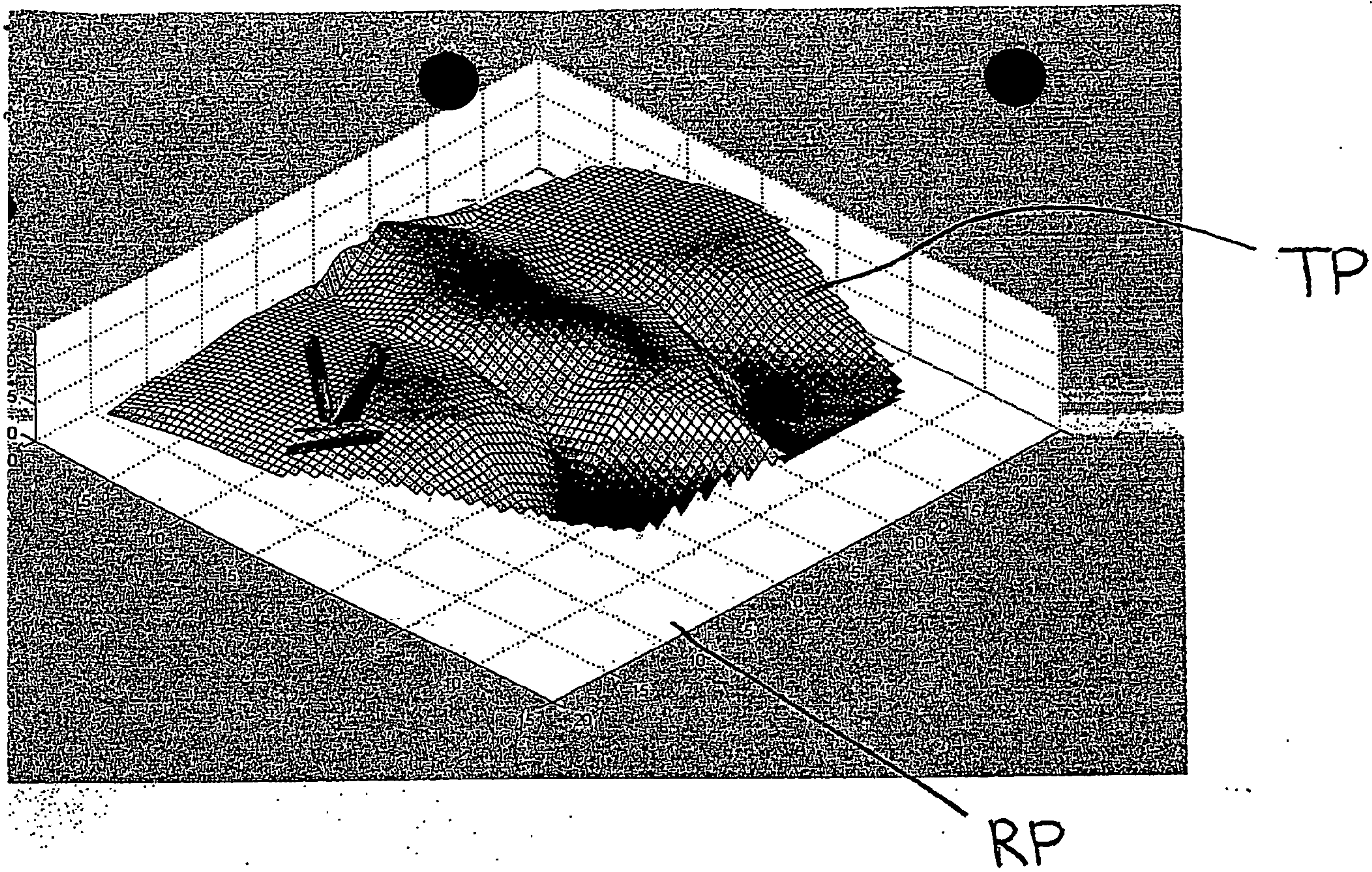


Fig. 5A

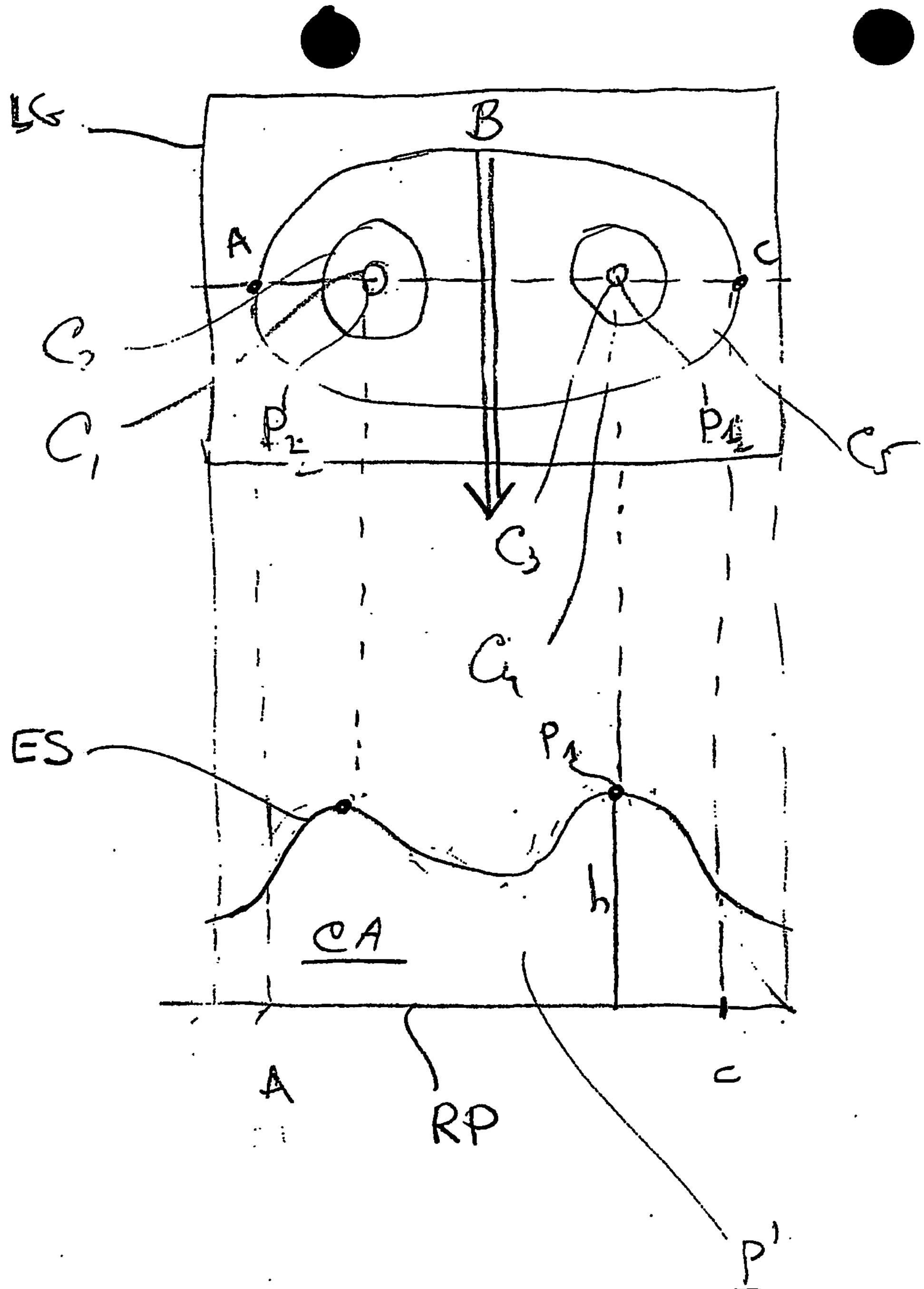
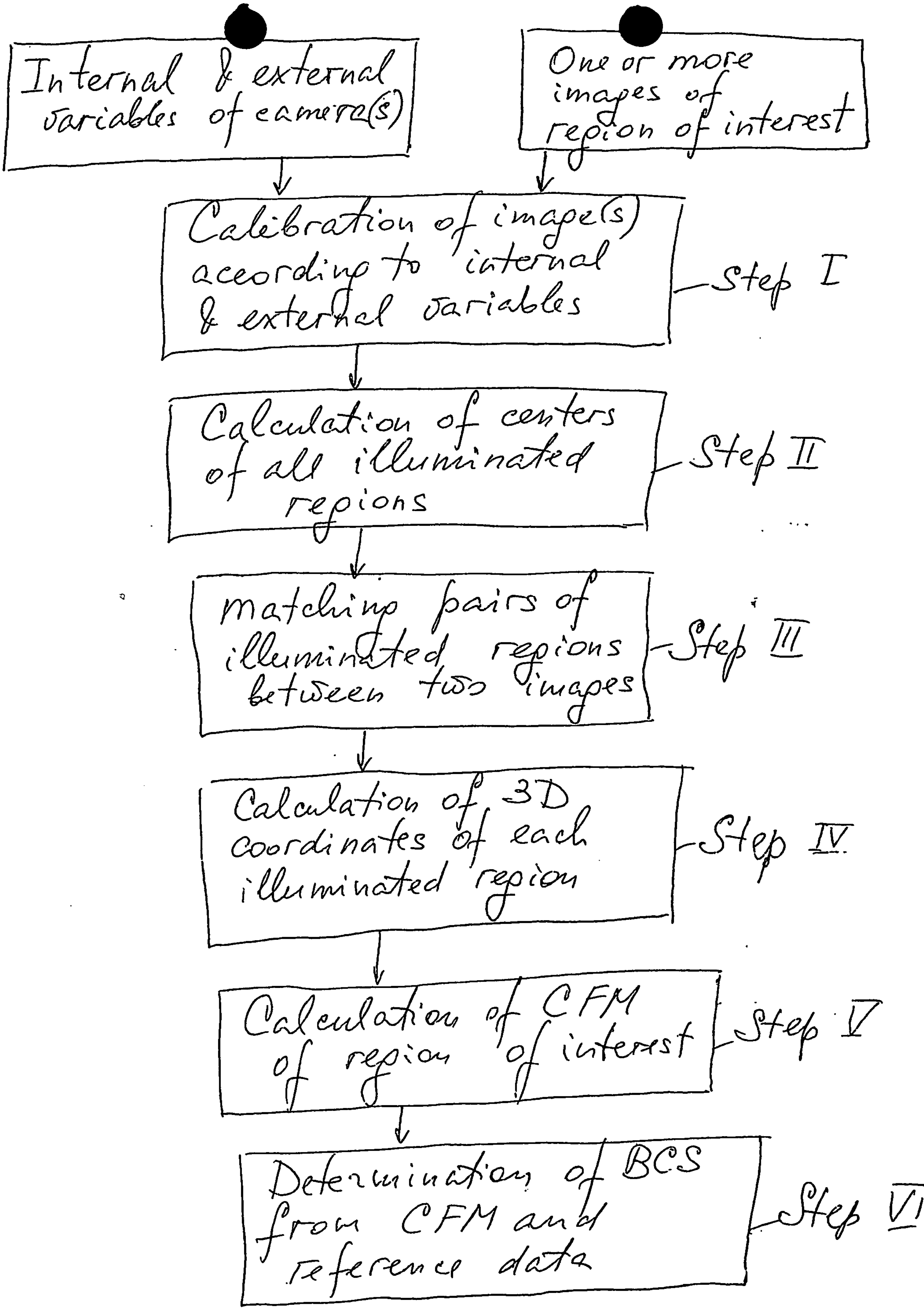


Fig. 5C

Fig. 5B


Internal & external variables of camera(s)
One or more images of region of interest
Calibration of image(s) according to internal & external variables
Step I
Calculation of centers of all illuminated regions
Step II
matching pairs of illuminated regions between two images
Step III
Calculation of 3D coordinates of each illuminated region
Step IV
Calculation of CFM of region of interest
Step V
Determination of BCS from CFM and reference data
Step VI